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AMERICAN SOCIETY OF CIVIL ENGINEERS

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WATER SUPPLY ENGINEERING

Report of Committee on Water Supply Engineering of the Sanitary Engineering Division for the Period Ending September 30, 1951

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS

WATER SUPPLY ENGINEERING

REPORT OF COMMITTEE ON WATER SUPPLY ENGINEERING OF THE SANITARY ENGINEERING DIVISION FOR THE PERIOD ENDING SEPTEMBER 30, 1951

The previous report of the Committee on Water Supply Engineering of the Sanitary Engineering Division was submitted by Chairman Thomas H. Wiggin, M. ASCE, at the annual meeting on January 20, 1949. This was the tenth report of the Committee under the chairmanship of Mr. Wiggin since January, 1933, when the first report was submitted. Mr. Wiggin resigned as chairman of the Committee in 1949, but agreed to continue to serve as a member. His contributions to the work of this Committee have been outstanding. The Committee desires to state its appreciation of his generous contribution of time and effort to the work of this Committee since its inception.

The 1951 report covers trends, developments, and events of interest to those in the water works field that have occurred during the period from January, 1949, to October, 1951.

There have been many trends, developments, and events of interest to those in the water works field during the period covered by this report. One noticeable trend is the general increase in per-capita water consumption, particularly in urban areas. This increase is the result of comparatively high employment and income and of the general improvement in standards of living and sanitation. Increased use of high quality water in new manufacturing methods and products also has increased water consumption. The general public desires plenty of good water and is willing to pay a reasonable price for it.

Another trend that has continued during the period covered by this report is the increase in cost of water works operation, maintenance, and construction. Many water works systems have found it necessary to increase rates to meet these higher costs and (in some instances) dissipation of reserves and curtailment of needed improvements has resulted from the decrease in net income.

One of the most serious problems facing water works officials today (1951) is the difficulty in obtaining certain materials, supplies, and equipment necessary for operation and expansion of their systems, because of controls resulting from national defense activities. Associations and leaders in the water works

NOTE.—Please forward all comments on this report directly to Chairman Ernest W. Whitlock, c/o Malcolm Pirnie Engrs., 25 West 43rd St., New York 36, N. Y.

and sewage works fields have cooperated on this problem and a Water Resources Division of the National Production Authority (NPA) has been established recently.

During the past few years there has been widespread interest in the development of a national water policy, or policies. Reports of The President's Water Policy Commission and of the Engineers' Joint Council (EJC) recommend entirely different approaches to the problem. They should be studied carefully by all who are interested in developing water resources. The policies that are finally adopted will have a great effect on the national economy. Recently, a number of studies and reports have been made on the development and protection of potential sources of water supply. These are discussed in this report.

The three-year period covered by this report has witnessed serious water shortages resulting in the necessity of curtailment of use and also unusual floods that have caused great damage. Fluoridation to reduce the development of dental caries by children has been adopted by many water systems. Other new developments of interest are the seeding of clouds to stimulate precipitation artificially, investigations in the reclamation of sea water, and the treatment of water to correct the effect of industrial and radioactive wastes. These developments, and other recent items of interest in connection with sources of supply works, distribution systems, treatment works, and water analysis and testing are described in this report.

Sources of Water Supply

Ground Water.—As of July, 1951, serious drought areas were developed in Southern California, Arizona, New Mexico, Utah, and Texas. Ground-water conditions in the southwest have been serious since the last report of this Committee. Elsewhere, ground-water conditions were normal except for local deficiencies.

In California, "The California Water Plan" (1)[1] will aid in establishing control over ground-water depletion. The annual pumpage of ground water from the alluvial valleys of California is estimated at 10,000,000 acre-ft. Overpumping of the formations is occurring and salt-water encroachment is resulting (2) (3).

In New Jersey, at least one third of the total volume of water consumed in the state comes from wells. In at least two areas, critical ground-water conditions have developed. By a law effective July 2, 1947, these areas—Monmouth and Middlesex counties with a total withdrawal of 64 mgd, and portions of Burlington, Camden, Gloucester, and Salem counties with a withdrawal of 77 mgd (4)—have been declared protective areas subject to restrictions as to further developments. However, it is not considered that the ground-water resources of the state as a whole have been depleted, even though local critical areas have developed. Measures are being taken to conserve supplies, and quantitative investigations are in progress (5).

In New England, a committee made up of one member from each of the New England states and one from the United States Geological Survey (USGS) inventoried and reported on ground-water supplies (6).

[1] Numerals in parentheses, thus: (1), refer to corresponding items in the Bibliography (see Appendix).

The most encouraging developments in ground-water supplies have been in connection with the artificial recharge of formations. Recharge projects have been reported from various localities. In Newark, N. J. (7), an experiment in using overflow water otherwise wasted from the Macopin Dam in New Jersey to flood an industrial intake area in Newark was conducted in 1948. This three-month experiment resulted in an increase in water level of 30 ft. In Nassau County, Long Island, New York, a ground-water recharge project has been operated with assistance from the USGS (8) (8*a*).

Further development in seismic prospecting of subsurface conditions—particularly to locate the depth to rock and to determine the general rock slope, in reconnaissance for ground-water development—has occurred since the last report. Eventual test-drilling and sampling of the soil should follow the seismic surveys. In a glaciated country, sites chosen from surface indications alone may prove unsuccessful because of the unfavorable location of bedrock. The seismic refraction method is used where depths of less than 200 ft are studied. Several such surveys have been made in New England to aid in locating ground-water supplies (9). Results may be unsatisfactory where narrow, deep, subsurface valleys are encountered, because of refraction from the canyon walls.

The well field at Miami, Fla., was in danger of complete loss because of salt-water intrusion during the droughts of 1944 and 1945. Intrusion could not be checked until controls were built in the drainage canals to keep a fresh-water head above sea level. Since these controls were installed, the advance of the salt-water face has been checked in most places (10).

One of the most comprehensive ground-water surveys in recent years was made by the USGS (11) in preparation of a report for The President's Water Resources Policy Commission. This report discusses the effect of land use practices, excessive withdrawal from wells, artificial recharge, salt-water encroachment and the status of ground water in the various parts of the United States. An appendix giving detailed summaries of ground-water conditions for each state is included.

Surface Water.—According to the United States Public Health Service (USPHS) inventory of water and sewage facilities in the United States in 1945, wells and springs furnish the public water supplies for 11,718 communities, while 3,652 use surface supplies (12). However, the supplies from surface sources total 8,902 mgd while the ground-water supplies total only 3,130 mgd. These supplies were served to 94,400,000 people. The average use per capita served was 127 gal per day.

When a change is made in a source of supply, the trend has been toward substituting a surface supply for a well supply, rather than the reverse. The Illinois State Water Survey collected information on ground-water developments since 1895 and submitted a report based in part on a list of 2,604 wells constructed for municipal supply in Illinois (13). In the seventy years ending in 1948, approximately 540 public ground-water systems were built in that state and between the years 1910 and 1945, 50 municipalities abandoned ground-water supplies for surface waters. In 1945, 210 Illinois municipalities were using surface supplies.

In the past many large urban centers have found it necessary and advisable to develop (at great expense) distant surface water sources to insure adequate future supplies, and this trend has continued during the past few years.

Effect of Dry Periods.—The importance of adequate public water supply facilities and the effect of unusually dry weather on surface water supplies were effectiviely dramatized by the campaign for water conservation in New York, N. Y., during and after the severe drought of the summer of 1949. This drought and the consequent lowering of reserves in storage reservoirs serving New York City, northern New Jersey, and other adjacent metropolitan areas, have impressed upon the public the necessity for providing adequate water supply facilities well in advance of needs.

The dependable yield of the sources of water supply for New York City in 1949 was estimated at a little more than 1,000 mgd. The last addition to the system was in 1927, when the Schoharie-Catskill system was completed. The need for large additional sources was recognized in the early 1920's, and in 1927 the Board of Water Supply of New York City submitted a plan for the development of the additional future supply that it considered most suitable. This involved carrying 100 mgd from Rondout Creek and 600 mgd from parts of tributaries of the upper Delaware River through a common diversion tunnel to New York City. In 1931, the United States Supreme Court limited the diversion from the Delaware to 440 mgd. The development of this project, which will add 540 mgd to the New York City water supply, was delayed by financial conditions during the depression years and by World War II. The Delaware Aqueduct was completed in 1944 and small quantities were diverted from Rondout Creek to the city.

In 1949, little water was available from the new source because the new reservoir on Rondout Creek, the two reservoirs on the branches of the Delaware, and their connecting tunnels were not completed. The reservoir on Rondout Creek is nearly completed (1951) and it is expected that the entire project will be completed in 1956. These additions will increase the dependable yield of New York City's water supplies to about 1,440 mgd, exclusive of well supplies on Long Island which the city wishes to discontinue. It is estimated that this will supply the needs of the city until about 1965, when an additional supply should be available. Several plans for this have been considered. These include (*a*) the development of the west branch of the Delaware River by New York City, (*b*) participation in the plan of the Interstate Commission on the Delaware River Basin for an interstate development of the waters of the upper Delaware River Valley, and (*c*) utilization of Hudson River water after treatment.

In May, 1949, the New York City reservoirs were all filled. A severe drought in the summer, accompanied by very hot weather, increased the average water demand to about 1,200 mgd, or somewhat more than 220 mgd over the dependable yield. Reservoir levels fell continuously to the extent that, in October, 1949, William O'Dwyer, then Mayor of New York, called on the public for conservation of the water supply. However, little was accomplished until the end of November. At that time, Stephen J. Carney, then Water Supply Commissioner of New York, started a campaign for conservation, using all

available sources of publicity, including the daily press, radio, television, instruction to school students, circulars, and display of posters in public conveyances and in all other available places. Early in December, 1949, the storage was down to one third of the available capacity and the daily press was devoting front-page space to the water supply situation.

The washing of automobiles, street sprinkling, sidewalk washing, and the operation of air-conditioning plants of more than 3-tons-per-day capacity (unless the plant was provided with a recirculating system) were prohibited. Water was served in restaurants only upon request.

New York City was not the only municipality with short water supply in the New York metropolitan area. Newark, Jersey City, and a number of other New Jersey communities, especially in the northeastern area of the state, also found that water supplies were rapidly disappearing.

By January, 1950, the daily consumption of New York City had been reduced from 1,200 mgd to below 900 mgd and was maintained at that low level even though the storage in the reservoirs recovered quite rapidly in the late winter and spring. In the fall of 1950, the increase in reservoir storage was sufficient to permit the majority of the restrictive requirements to be lifted. However, in the summer of 1951, the consumption of water had again risen to approximately the dependable yield. Meantime, a 100-mgd emergency pumping plant was constructed by the city to take water from the Hudson River at a point near Chelsea, N. Y., and deliver the water into the Delaware Aqueduct.

The nationwide publicity given to the shortage in the water supply for New York City and the New York metropolitan area resulted in the printing of numerous water supply articles in the popular magazines, and a general rise in popular interest in the adequacy of the water resources of the continental United States.

Drought conditions have prevailed for the past three-year period in Southern California, Arizona, and New Mexico. During 1950, this condition extended into parts of Utah and Colorado (14). It has continued more or less unchanged up to the present time. In the San Diego (Calif.) area, stream runoff has been below normal for the past ten years.

Floods.—In the period covered by this report, there have been occasional local floods of unusual magnitude that have caused great destruction and have damaged water supply systems. Outstanding and widespread damage was caused by the flood of the Red River and the Assiniboine River in April and May, 1950 (15).

According to the USGS (16), the floods of July, 1951, exceeded all previous records in at least four Kansas streams: The Kansas River and the lower Smoky Hill River, one of its main tributaries; the Marais des Cygnes River, a Kansas tributary of the Osage River, which enters the Missouri below Jefferson City, Mo.; and the upper Neosho River, in southeastern Kansas. The Missouri River itself, between Kansas City, Mo., and St. Louis, Mo., reached about the same stages as during the flood of 1844, more than a century before the highest flood known previously. These floods rendered the water supply systems of

several small communities temporarily useless, and drowned out the Turkey Creek Pumping Plant of the Kansas City (Mo.) system (17)

According to an isohyetal map of the flood area prepared by the United States Weather Bureau, the total rainfall for the two-week period from July 4 to July 17 showed several peaks of more than 15 in. in the area covering eastern Kansas, west central Missouri, and southeastern Nebraska, with the bulk of the rain occurring between July 10 and July 13.

A notable flood peak, probably a record for Kansas, was 439,000 cu ft per sec for the Neosho River near Parsons, Kans., or 91 cu ft per sec per sq mile for 4,817 sq miles of drainage area. Another peak was 24,000 cu ft per sec for the 20 miles of the East Fork Fishing River at Excelsior Springs, Mo., or 1,200 cu ft per sec per sq mile. The Solomon River at Bennington, Kans., is estimated to have carried a million tons of sediment on July 14, 1951, with a flow of 149,000 cu ft per sec. The enormous damage done by the Kansas flood of July, 1951, was estimated to be of the order of a billion dollars. The American National Red Cross listed 180,420 persons either driven from their homes or stranded by high waters.

Erosion Control.—Many important water supply projects throughout the United States are subject to sedimentation, debris pollution, and other forms of damage resulting from erosion of the watershed lands (18).

Deposition of soil and other materials in reservoirs used for water supplies, irrigation, or power development, often causes not only a reduction in the storage capacity of the reservoir but also a reduction in the quality of water available for use. In 1949, the Soil Conservation Service (SCS), United States Department of Agriculture, estimated—from the results of its surveys and investigations—that more than 33% of the water supply reservoirs will have to be supplemented or replaced before they are fifty years old because of the loss of capacity as a result of sedimentation.

During 1949 and 1950, many cooperative agreements were made between the owners and operators of storage reservoirs and the SCS whereby that service conducted the necessary investigations and prepared reports on the work that must be undertaken to reduce soil erosion and to decrease the amount of sedimentation in the various reservoirs. Programs adopted by some agencies interested in this work have included the following principal items: (*a*) The construction of check-dams to reduce the grade of drainage channels; (*b*) the building of earth or masonry dams to form silt-catching basins; (*c*) tree planting; (*d*) bank protection; (*e*) planting of slopes; and (*f*) range management.

Wherever the foregoing programs have been carried out, the results have been very encouraging and there has been a definite reduction in the sedimentation at the reservoirs involved.

Progress in Industrial Pollution Control.—The general policies involved in pollution abatement were discussed by T. R. Camp, M. ASCE (19), during the period covered by this report. L. L. Hedgepeth (20) described his experiences in the abatement of industrial pollution.

On June 30, 1948, Public Law 845, officially cited as the "Water Pollution Control Act," went into effect. Under this law, the federal government provides aid to state and interstate agencies, and to industries, in research and in making

surveys and investigations. Provisions were made for loans and grants for remedial works, but no appropriations for such have been made to date (1951). The USPHS administers the sections of the law devoted to research, surveys, investigations, and technical assistance. Since the law was passed, the USPHS has set up fourteen river basin offices, prepared a report on water pollution (21), and assisted both financially and technically in much valuable research in methods of treating wastes (22).

The National Council for Stream Improvement (of the pulp and paper industry) (23) (24) has been particularly active in giving advisory service and doing fundamental research in the waste disposal problems of the pulp and paper industry.

A critical period in the existence of the presently constituted Ohio River Commission occurred in 1950 when the state auditor of West Virginia refused to honor requisitions covering the state's portion of the commission's operating funds. His refusal was upheld by the Supreme Court of Appeals of West Virginia, but the decision was reversed by the United States Supreme Court (25) in 1951, which ruled unanimously that the compact was "valid and binding upon West Virginia." The commission continued to progress in its program of pollution abatement (26).

In the Baltimore (Md.) area, extensive industrial pollution of ground-water aquifers is being studied to determine the distance through which the pollution may be carried. In the Luke-Cumberland area of the Potomac River Basin, there is extensive pollution that will be alleviated somewhat when operation of the Savage River Dam increases minimum flows. However, the problem cannot be considered solved (27).

The Pennsylvania clean stream program (28) was begun in 1937 and has been accelerated steadily since 1945. During 1949, the Sanitary Water Board of Pennsylvania adopted the policy of notifying all municipalities and polluting agencies in the Delaware River drainage area (including in this area the Schuylkill River) to undertake construction of treatment works. In the Schuylkill River area the state-federal desilting program is progressing successfully and all the headwater collieries have installed desilting works. The Interstate Commission on the Delaware River Basin has been active in promoting and coordinating a program for the control of pollution of the Delaware River and its tributaries since it was organized by the cooperative action of New York, New Jersey, Pennsylvania, and Delaware in 1936. Much additional pollution abatement work is being done throughout the state.

In 1949, the State of California passed legislation to implement preliminary action taken in 1947 (29). Regional water pollution control boards were established for solving local problems, and water quality criteria were established.

The New York State Legislature adopted a pollution law in 1950 (30), which provided for the classification of New York surface waters according to best usage, and provided standards for such waters.

During the past few years increasing attention has been given the effect of radioactive wastes, the quantities of such wastes that can be tolerated, and methods for the removal of excessive amounts. Water decontamination re-

search is being carried out by the Oak Ridge National Laboratory (Oak Ridge, Tenn.), and by several universities under the sponsorship of the Atomic Energy Commission.

Because radioactive products are rare and costly, the reclamation of products from wastes is economically feasible on a large scale (31). As a result, water pollution from this type of manufacturing activity is ordinarily at a low level, and only through accidental "spills" is there any danger of contamination of down-river supplies.

Investigations have been made (32) that tend to show that radioactive phosphorus can be removed by water treatment processes. A. E. Gorman, M. ASCE, in discussing this reference, states:

> "Much more research will be needed in this field before the effectiveness of orthodox water purification methods in removing all radioactive contaminants from water are established with the same degree of surety that is customary in the profession in dealing with other contaminants."

A method of decontaminating small quantitites of radioactive water has been developed at the Oak Ridge National Laboratory (33).

The foregoing progress is cited to show that efforts to improve water quality in streams are progressing and will ultimately result in raw water of higher quality reaching many plants that treat surface waters.

Developments in the Control and Allocation of Water.—In the western states, the principal interest in the control and allocation of water centers around the utilization of the water of the Colorado River. The controversy regarding the Central Arizona Project, now (1951) pending before Congress, has received much attention but no decision has as yet been reached. The settlement of this long-standing difference of opinion between California and Arizona can be made possible only by judicial interpretation of existing fundamental documents (34) (35).

In 1949 and 1950, legislative authorization made possible continued investigation by the California State Division of Water Resources, under the direction of the state engineer, toward the revision and completion of the state water plan. Its objective is the preparation of a plan for the full conservation, control, and utilization of the state's water resources—to meet present and future needs for all beneficial purposes in all areas of the state. This has been designated "The California Water Plan" (36). Work on thirteen special investigations by the California State Division of Water Resources is being coordinated with the statewide investigation for the state water plan. This statewide investigation program is probably one of the most extensive and important water supply studies ever undertaken by any state or public agency, and when completed it will serve as a definite guide for the full utilization of California's water supply.

The basic laws affecting control and allocation of water throughout the United States have been summarized by the American Water Works Association (AWWA) (37). Similar information is given by the USGS (38).

The Design of Supply Works

Dams and Spillways.—A new overflow type of dam of novel design has been built on the Patapsco River to divert water into the water supply system of Baltimore. The crest of the dam is approximately 225 ft long and approximately 16 ft above the river bed. The crest has a 3-ft depression at the midpoint. The slope of the upstream face of the dam is one on three, and of the downstream face, one on four. Both faces of the dam are paved with concrete that is 12 in. thick and reinforced with steel bars. A central core wall of concrete extends into solid rock from 4 ft to 6 ft below the stream bed. Upstream from the core wall, the mass of the dam is concrete masonry, and downstream from the core wall it is rock fill made from tunnel spoil (39).

Experience gained in grouting the foundations of twenty or more large dams has led engineers of the Bureau of Reclamation (USBR), United States Department of the Interior, to conclude (40):

> "Most of the future dams to be built on rock foundations will require some form of foundation treatment. * * * Neat cement is still the most effective grouting material where permanence and strength are prerequisites. Certain admixtures are sometimes used under special conditions; but, generally, they offer no advantage in foundation grouting. Hot asphalt has proved effective in stopping large flows of water that could not be controlled by cement grout."

In the design of concrete masonry dams of the gravity type, it has been a common practice with some engineers to assume that uplift pressure on the base varies uniformly from full-reservoir pressure at the upstream toe to tailwater elevation or zero (as the case may be) at the downstream toe, and that the pressure acts over two thirds of the base area. Observations, made by engineers of the USBR (41) of uplift pressures measured at several dams over comparatively long periods, seem to indicate that this design basis of uplift may have been higher than necessary.

The experiences of the New York City Board of Water Supply in the construction of the Merriman, Neversink, and Downsville earth dams, have shown the value of sinking one or more exploratory concrete caissons to deep bedrock, through the overlying water-bearing glacial and water-borne deposits. All of these dams are in New York State in the upper Delaware River Basin. These caissons are helpful in demonstrating the feasibility of lowering the groundwater level, in determining (to a larger scale than by borings) the nature of the soil formations, and in providing a pump well for use during the subsequent construction of the cutoff wall of the dam (42). The maximum depth of the water-bearing material at the center line of the dam at the Merriman site was about 180 ft; at the Neversink site, 150 ft; and at the Downsville site, 110 ft. In addition to pumping from the caissons, the ground water has been lowered by means of deep wells, by pumping from the open cut, and by continuous pumping from successive tiers of wellpoints.

The British practice relative to the construction of the central watertight barrier in earth dams is as follows (43):

"Earth dams in Britian are made with a central watertight barrier which is carried down into strata which are or can be made watertight. This barrier is known as the 'cut-off' where it is below ground, and the 'core-wall' where above ground.

"Quite often in the older dams in this country both the core-wall and the cut-off were made of clay, but it is now better practice to fill the cut-off trench with concrete and construct the core-wall of puddled clay, the reason being that, when subterranean leakage occurs, clay may be exposed to erosion if the escaping water comes in contact with it."

In the United States, it was common practice some years ago to build a core wall—including the cutoff below the original surface—of masonry, and to carry the core wall to nearly the full height of the earth dam. Examples of this are found in the earth dams built for the water supply of the City of New York from the time of the Middle Branch (Croton) Reservoir structure, placed in service in 1878, to and including the Ashokan earth dikes completed in 1915.

There are conditions that may justify the use of a concrete core wall, such as—(*a*) locations where relatively impervious soil cannot be obtained except at prohibitive cost, (*b*) dams of relatively low height and small cross section, and (*c*) requirement by statutory authority. The tendency now is as follows (44):

"Where there is good impervious material near the proposed dam site, its use for a central core will usually be found more economical and more desirable than the use of a concrete core."

The three large rolled earth dams now under construction (1951) by the Board of Water Supply of the City of New York are typical examples of earth dams that do not have a central masonry core wall extending up to the flow line, but have only a concrete cutoff wall extending from bedrock up into the rolled embankment to about one third of the height of the dam above the original surface of the soil.

The consolidation of materials in earth dams and in their foundations is a subject to which much study and research is being devoted. Laboratory investigations of soils, the compaction of fills under field conditions, the relation of the compaction of fills to the design of the embankment, and the actual performance of fill on varying types of foundations, must be considered as vital parts of the whole problem of embankment design and construction (45). Further investigations and observations are needed.

Factors other than mechanical properties are also important in determining the stability of an earth structure. These are the geochemical processes and products and the mineralogical changes that occur when soils are excavated, exposed to the action of air and water, and worked into an embankment or fill (46).

Pipe Lines and Tunnels.—Some progress has been made in the development of flange standards (47) for water pressures lower than 230 lb per sq in., in all sizes and diameters larger than 24 in., the upper diameter limit of existing standards of the American Standards Association.

In recent years, steel pipe of large diameter has been used for important aqueducts such as the second Mokelumne Aqueduct and the Los Angeles Bouquet Canyon inlet-outlet pipe line (California), resulting in standards of

conservative design based on experience (48), which are of great value to designers of such pipe lines.

The design of prestressed concrete cylinder pipe has been improved as experience has been accumulated, not only from hydrostatic and crushing tests, but also from observations of pipe in actual service (49) (50). Better information concerning such pipe lines, for diameters of from 16 in. to 60 in., is now available to aid the designer. Tentative standard specifications for reinforced concrete water pipe of the prestressed steel cylinder type have been prepared by a committee of the AWWA (51).

Although several notable water works tunnels were driven during the period of this report, little that is new in methods and equipment was developed. In 1950, the New York City Board of Water Supply published a volume describing the New York City water supply system (52). This book provides much valuable information on tunneling as well as excellent historical and descriptive data on the entire system.

Pumps and Pumping Stations.—The most notable recent development in pumping equipment is in connection with the Hudson River Pumping Station of the Board of Water Supply of New York City, an installation described previously in this report. Specially designed submerged turbine pumps were used. These were of the vertical-shaft, multistage type, driven by electric motors of 2,500 hp. Each pump had a rated capacity of 20 mgd at a total dynamic head of 600 ft (53). The design of this pumping station is illustrative of a recent trend toward vertical-shaft submerged pumps for water intake pumping stations.

An increase in the use of automatically-operated pumping stations has been noted in recent years as a means of reducing operating costs. Milford E. Rogers, M. ASCE, has summarized and discussed this trend and the various methods of accomplishing automatic operation. His references include typical examples of such control (54). E. Condict (55) discusses proper pump selection as related to economy of operation.

The use of traveling water screens remains a favored method for removing trash from water entering intake pumping stations, but—where hydraulic and physical conditions are suitable—hydraulically backwashed well screens that are mounted vertically may be used at substantial savings in operating costs (56).

Distribution Systems

Analysis and Design.—Interest has been renewed in electrical methods of analyzing distribution systems. M. V. Suryaprakasam, A. M. ASCE, and others (57) have devised a method by which a commerically available a-c network analyzer using linear relationships can be used for distribution system analysis by use of a correction factor. Twenty-two such analyzers are stated to be in existence. M. S. McIlroy (58) has designed and built an electric analyzer using nonlinear resistors that have volt and ampere characteristics analogous to head loss and flow characteristics of a pipe line as expressed by the Hazen-Williams formula. These tools, if they become available to the water works engineers, may be very helpful generally in solving distribution problems.

Types of Pipe.—Cast iron pipe made by the centrifugal process in metal molds or sand-lined molds continues to be the pipe most often used in distribution systems. Some pit cast pipe continues to be used, especially the larger sizes. There has been a gradual substitution of equipment for the manufacture of centrifugal pipe in metal molds in place of equipment for casting pipe in stationary molds.

The use of cement asbestos pipe continues on a gradually increasing scale, but no statistics are available as to whether it has increased relative to the total quantity of pipe of all kinds.

The use of prestressed pipe containing a steel cylinder is increasing. Some idea of the magnitude of the business is the fact that a large manufacturer of this type of pipe reports sales of more than 1,000,000 ft in 1950 and 1951, as compared to about 650,000 ft of concrete pipe with a steel cylinder that is not prestressed. A substantial quantity of concrete pressure pipe, particularly in sizes from 16 in. to 30 in. in diameter, is now made in permanent plants in the east and the middle west and shipped by truck or railroad to the project location. For heads of up to about 100 ft, concrete pipe without a steel cylinder has been used in some instances.

The demand for all kinds of pipe has been so great as to use all available capacities.

Protective Coatings for Pipe.—The Committee has continued the investigation of progress in providing better types of protection for the interior of cast iron pipes. A comparison of replies to questionnaires sent to five manufacturers indicates an increase in the use of a cement-lined coating of standard thickness with a bituminous seal coat. However, other linings such as a thin mortar lining protected by a bituminous spray coat, a tar-dipped lining, and a bituminous spray coating have been used on a considerable portion of pipe recently made.

Cement Mortar Lining of Pipe in Place.—During the past three-year period the most active company engaged in lining pipe in place with cement mortar has lined more than 1,000,000 ft of cast iron and steel pipe having diameters of from 16 in. to 144 in. During this period it has developed equipment for lining pipe of 16-in. diameter by the centrifugal method. A considerable amount of pipe of this size and smaller has been lined during the period of this report by the mandrel method, particularly in the west coast states.

Prestressed Concrete Water Tanks.—Prestressed, cylindrical concrete tanks continue to share the market with steel tanks. These tanks are of various designs. Many are entirely of gunite with bottoms 2 in. thick, not prestressed but reinforced by wire mesh. The sides are prestressed using high tensile wire, and the roof is usually of dome construction. Others have poured bottoms, gunite sides with prestressed rods, and gunite dome roofs. Sides of prestressed poured concrete are used in some instances. One maker states that such tanks are not normally in successful competition with steel tanks in sizes below 500,000 gal, but that they have shown decided economy in sizes of 1,000,000 gal and larger.

One company specializing in prestressed concrete tanks reports that between July, 1935, and July, 1951, it has constructed 690 tanks having a total

capacity of 536,000,000 gal. This list includes, besides water tanks, 107 sludge digestion tanks having a capacity of 187,000,000 gal.

Galvanic Electric Current in the Mokelumne Pipe Lines.—The Mokelumne Aqueduct of the East Bay Utilities District, California (59), is composed oftwin steel pipe lines with bituminous coatings. Shortly after the second line was installed, investigation showed that galvanic electric current was building up on the new pipe and flowing in the direction of the cross-connections between the two lines and then along the cross-connections to the old pipe. The current then followed the old pipe to the areas of low resistance soils, where it was discharging through weaknesses in the protective coating to the ground. To complete the circuit, the current was picked up again on the new pipe coated with a cement mortar. Studies indicated that the two pipe lines formed a galvanic cell in which the second pipe line was the cathode and the first pipe line was the anode.

These conditions were corrected by installing insulating joints in the cross-connections between the two lines to prevent the flow of current from one line to the other and also by installing a number of insulating joints in the second pipe line to prevent the flow of current along that line. The current flow has been effectively reduced by these protective measures, and the installation of several additional cathodic protection stations on the old line has practically eliminated the flow of current from that line to the ground, thus eliminating a previous cause of leaks.

Design of Treatment Works

Coagulation.—No important change has been made in the past several years in the design of facilities to coagulate and settle water. For municipal plants where the water is not softened, aluminum sulfate continues to be the most widely used coagulant. The use of iron compounds has not increased, and may have decreased slightly. To a limited extent, acid-treated sodium silicate is being used to aid the coagulation of water that is difficult to treat. For most waters, no unusual difficulty is experienced with aluminum sulfate or one of the iron compounds and no coagulation aid is needed. The silicate treatment strengthens the coagulation and usually results in more well-formed flocculation and more rapid sedimentation. This treatment is adapted to all the present designs for mixing and sedimentation.

The 1951 report of a committee of the AWWA (60) describes eight devices being offered by different manufacturers. This committee, in its 1949 report, presented at the Chicago Conference of the AWWA stated:

> "Finally the committee was able to agree that alum floc in suspended solids contact basins seems to be subject to the same breakage and disintegration from rough handling as alum floc in any other type basin. Calcium carbonate slurries, on the other hand, as generally formed in lime softening, seem to be fully resistant to destruction from agitation. The character of the mixing required to these basins demands the same careful consideration given to that of other mixing and conditioning basins. For example, too violent mixing for too long a time will cause serious floc destruction and result in uncoagulated water * * *."

Following the 1949 report, this AWWA committee mailed questionnaires to approximately two hundred operators of suspended solids contact basins. Almost all the operators believed that a slurry pool or sludge blanket is essential for proper coagulation. Replies to the question of the required detention period specified from slightly less than 1 hour to approximately 3 hours. The majority of the replies stated that the basins provide adequate safety factors. The quantity of waste water ranged from 0.25% to 7% of the influent for softening plants and from 0.50% to 12% of the influent for clarification of turbid surface waters. Widely varying experiences were reported as to the effect of organic material in the slurry pool or sludge blanket. Floc carryover, under average conditions of operation, is relatively unimportant. Changes in the rate of flow do not have much influence so long as the rate is between about one half and full capacity.

Water Softening.—Louis R. Howson, M. ASCE, reviewed the economics of water softening in a paper published in April, 1951 (61). He states that the cost of softening hard water is outweighed by the saving that results from the softening. In places where the hardness of the water is 125 ppm or more, he recommends that serious consideration be given to the installation of softening equipment to supplement purification in the design of new filtration projects. If this recommendation is followed, cities using the Lake Michigan water should give consideration to softening, a practice not generally followed heretofore in the design of filtration plants in such cities. The hardness of the Lake Michigan water at Chicago, Ill., averages about 130 ppm. Chicago's South District Filtration Plant is designed so that it can be operated as a softening plant. So far, softening has not been used except for trial runs on one third of the plant. Preliminary design of the Central District Filtration Plant for Chicago does not include provision for softening.

In the plant of the Metropolitan Water District of Southern California, Colorado River water is softened from an average of 320 ppm to 125 ppm (62). The most significant recent development in plant operation has been the improvement in economy of base-exchange softening effected by the use of polystyrene resinous cation exchanger instead of the synthetic siliceous zeolite previously used. Investigations at the plant indicate a softening life of at least 6,000,000 gal of water softened per cubic foot of the resinous exchanger without appreciable loss of economy, and a possibility of much longer life as no deterioration has occurred to date in this material under continuous pilot plant tests for more than four years. Ten years' experience with synthetic siliceous zeolite has shown the economic softening life to be approximately 2,000,000 gal of Colorado River water per cubic foot of zeolite. Consumption of salt for the regeneration of synthetic siliceous zeolite has ranged from 0.3 lb to 0.5 lb of salt per kilogram of hardness removed, the larger consumption applying to zeolite near the end of its useful life. The salt consumption of regeneration of the resinous exchanger has been only 0.2 lb per kg to 0.3 lb per kg of hardness removed.

The economic relationship between softening processes at the water treatment plant has changed, the exclusive use of base-exchange softening now being more economical than the lime-zeolite method that was used for many years.

This is because of (*a*) the advantages of using the resinous exchanger, (*b*) the considerable increase in the cost of time, and (*c*) the continued availability of salt at the 1941 price. The result is that the use of lime for softening has been largely discontinued except for increasing the softening capacity of the plant during summer peak flows.

An electrolytic water softening pilot plant with a capacity of 150 gal per min was constructed in 1949 by the Metropolitan Water District of Southern California and has been in continuous operation since January, 1950. This project is an outgrowth of experimental work on electrolytic softening previously conducted for several years using small units set up in the laboratory of the water district. The pilot plant was designed for more complete investigation of the operating characteristics of a commerical size unit and has served to confirm the data previously developed as to the quality of water obtainable and the approximate power requirements for effective treatment. Further investigation is being made of operating procedures and costs.

Regeneration of sodium zeolite, using sea water, continues to be used where conditions are favorable. In Florida, three plants of this type are now in operation.

Filter Design.—The elements of filter design have been reviewed in an article by Richard Hazen, M. ASCE (63). Consideration is given to filtration media, underdrain systems, rates of filtration, and surface wash systems. Although many filter plants turn out good water and the filters are kept in reasonably good operating condition, the filters in many other plants have comparatively short lives because the backwashing disturbs the sand and gravel beds. The success of a rapid sand filter depends as much on the proper design and construction of the underdrain system as on any other single factor. Probably the most common cause of failure in filters is an uneven distribution of wash water. Mr. Hazen advocated head loss of from 8 ft to 12 ft at normal rates of backwash to insure even distribution. This is more than is generally provided in filter design. Either sand or anthracite coal is satisfactory for the filter media.

High rates of filtration are satisfactory as long as the pretreatment of the water is good, and the amount of floc going into the filters is not excessive. Review of recent design data indicates that most designers still hold to the rate of 2 gal per min per sq ft. Extensive use is being made of surface wash systems. Mr. Hazen's comparison of the percentages of surface wash water needed shows decided favor for the high-pressure, revolving-jet type. Filter beds are maintained in excellent condition in the Chicago plant with only 5% of the total wash water used passing through the surface wash and with pressure of only about 10 lb in the piping close to the jets. The total wash water in this plant amounts to 1.6% of the water filtered. This would indicate greater economy for the fixed-jet type.

Air transmitters for filter gages and other gages are proving to be practical and economical. In the Chicago plant, each of the 80 filters is equipped with air actuators for the rate of flow and loss of head gages. The sand expansion gages are also air-actuated. The filter rate controllers are connected to summators by air lines and the total flow is thus summed.

Developments in the field of diatomite filtration for public water supplies continue to be largely along the lines of research (64). Los Angeles (Calif.) studies have indicated the ratios of various factors between diatomite filtration and conventional filtration.

Corrosion Control.—Most of the corrosive waters are being treated with lime or sodium hexametaphosphate (Calgon). The use of Calgon is being extended, and apparently is the most satisfactory treatment for some waters. Marshall Wellington, sanitary engineer of the New Haven (Conn.) Water Company, reports successful use of Calgon for seven water plants owned by this company (65). The treatment was started with the use of 4 ppm of Calgon and was later reduced to 2 ppm. Materials that have been found satisfactory for handling Calgon are rubber hose, hard rubber pipes or rubber-lined pipes and fittings, plastic pipe or tubing, stainless steel 316, and earthenware crocks. In starting a treatment, the material may be properly used at a rate of 10 ppm, while hydrants or blowoffs on the end of the system are held open until metaphosphate is found in the water. The dosage then can be reduced to from 2 ppm to 3 ppm. Mr. Wellington states that the water must be kept flowing through the zone of protection. Dead ends and hydrant branches will not be protected.

Taste and Odor Control.—The single most important treatment in taste and odor control continues to be activated carbon (66). Free residual chlorine (67) (68) has proved an aid in many instances, and during the past few years chlorine dioxide treatment has been established as an accepted treatment method. R. Aston (69) summarized recent development and publications. By late 1949, approximately 120 plants were using chlorine dioxide, mainly for taste and odor control. As customarily used, chlorine dioxide is made at the plant by mixing a solution of sodium chloride with chlorine water in a chemical ratio of from 1:2 to 1:1 by weight, and dosed to produce a chlorine dioxide concentration of between 0.2 ppm and 0.3 ppm.

Ozone (70) is being used at the Belmont Plant in Philadelphia, Pa., for the control of tastes and odors. At the time that the reference article was published, low odor intensities had prevented a real test of the system.

Disinfection.—Chlorine remains the most commonly used chemical for disinfection of water. P. W. Kabler (71) reviewed the history of chlorination and discussed at length the influence of pH, temperature, and genus sensitivity. His article has a complete bibliography on the resistance of organisms to chlorination. Increased use of free residul chlorination for disinfection as well as for taste and odor control is noted.

At the South District Filtration Plant in Chicago, the raw water is chlorinated to the extent that the water passing the filters has about 0.5 ppm of free residual chlorine. A slight additional amount of chlorine is added to the filtered water to give 0.6 ppm of residual chlorine to the water leaving the plant. When there is ammonia pollution in the water, 2 ppm to 3 ppm of chlorine are required to produce this residual. All free ammonia is destroyed by the treatment. Usually less than 0.1 ppm of combined chlorine remains in the water. This type of chlorination is commonly called "breakpoint chlorination."

Chlorine dioxide (69) has also proved effective as a bacteriacide, wherever needed, and for taste and odor control. The use of ozone as a disinfectant has been of minor importance during the past few years.

Fluoridation.—About twenty years ago, the cause of mottled teeth was determined to be the result of excess fluorine in the water supply, consumed by children during the years in which the teeth were forming and erupting. Approximately ten years later, investigators concluded that the presence of fluorine in water supplies in amounts of about 1.5 ppm made teeth much more resistant to decay to the extent of approximately 60% reduction in dental caries.

To determine whether fluorine added to a water supply would give similar results in systems where fluorine was a natural content of the water, fluorides were first added to the water at Grand Rapids, Mich., starting on January 25, 1945. Other communities that started adding fluorine that year were Brantford, Ont., Canada, and Newburgh, N. Y. (72).

After 1945, the cities adding fluorides increased slowly until favorable reports were received from the pioneer cities using fluoride treatment. Thereafter, the interest in fluoridation greatly increased. A survey made early in 1951 (73) showed that forty-one state health departments had adopted a policy permitting fluoridation and since then at least two more have adopted such a policy.

The survey indicated that 68 communitities were using fluorine in the water supply and that 42 of these communities were located in Wisconsin where the state health department was actively advocating the addition of fluorides to the water supplies. An additional 88 communitites had received state health department approval for the addition of fluorides, with 68 more having requests pending for approval of fluoridation.

The chemical used has usually been sodium fluoride, although the use of sodium silicofluoride has rapidly increased because of its much lower cost. As the addition of fluorides to the water supply has seemed so far to be the most effective way of substantially reducing dental caries, and as the cost has been found to be approximately 10¢ to 15¢ per annum per capita, it is probable that this practice will spread rapidly unless some better procedure is discovered for reducing the number of dental caries.

Most of the cost of treatment is for the chemical, which is usually a by-product and therefore sold very cheaply. Indications are that the price of chemicals containing fluorine will rise as a result of their increased use in industry and water supply treatment.

Water Analysis and Testing

An important development in water analysis and testing during the past three years has been the improvement of titration methods for determining hardness. The Schwarzenbach (Versenate) method, developed in Switzerland, was shown by various workers in the United States (74) (75) (76) to be a rapid, sufficiently accurate method. Although the chemistry of the titration is complex, the mechanics are simple. Apparently, the operation can be per-

formed in about one half the time required for determining hardness by using soap, and is somewhat superior in accuracy.

A consistent trend toward greater instrumentation of water laboratories is apparent. The use of pH meters is becoming standard in all except the small plants. In addition, photometers and spectrophotometers are becoming common for use in colorimetric determinations. Amperometric titrations for chlorine residual have displaced colorimetric procedures in many cases. Other instruments are used in larger laboratories. Some laboratories are installing monitoring devices for detecting the presence of radioactive wastes in waters. Apparently, this equipment is still in the development state, and may require improvement before it is satisfactory for general use. The AWWA has recently established a committee on instrumentation and methods of testing radioactive contamination of water. Common usage is well outlined by S. K. Love and J. R. Baylis, A. M. ASCE (77) (78).

New or improved methods for analyzing polluted waters for the occurrence of metals are described by P. G. Butts, A. R. Gahler, and M. G. Mellon (79). They take into consideration the effect of interfering ions.

Notable Construction

As in the past, this Committee has included in its report a brief description of some of the important water supply projects completed, under construction or contemplated during the period covered by the report. This is not intended as an inventory of all important work, but only as comments on some of the important projects that the Committee feels will be of interest to members of ASCE. Many interesting water developments are for irrigation, power, navigation, or related uses and have not been included here. Only projects contributing to municipal water supply have been mentioned herein.

Boston (Mass.) Metropolitan District.—The city tunnel section of the Hultman Aqueduct, which had been under construction since 1947, was placed in service during November, 1950. Provisions have been made at the top of the tunnel's shaft No. 6 for a pumping station to supply water to the City of Newton, Mass., and construction of this station should be completed early in 1952 (80).

Bids were opened in May, 1951, for shaft No. 9-A in Malden, Mass., of the proposed City Tunnel Extension. The proposed tunnel section, 10 ft in diameter and about 7 miles long, will be a pressure tunnel and will extend in a northeasterly direction from the Chestnut Hill section of Boston to the City of Malden, where connections will be made to existing distribution lines and to the Fells Reservoir.

Additions to the south site of the district include 20-in. and 24-in. prestressed concrete and 48-in. steel distribution pipe lines, totaling 9.5 miles in length, and a distributing reservoir in the Blue Hills with a storage capacity of 130,000,000 gal.

The Chicopee Valley Aqueduct has been completed and is in service. This is a steel cylinder reinforced concrete pipe line 48 in. to 36 in. in diameter built from the outlet works of Winsor Dam of the Quabbin Reservoir, in Massachusetts, to the Chicopee, (Mass.) city line (81).

The Board of Water Supply of New York City.—Rapid progress has been made toward the completion of the current program of diverting water from Rondout Creek, Neversink River, and the east branch of the Delaware River to New York City. Merriman Dam on Rondout Creek is nearly complete and the reservoir is being filled with water. Work on Neversink Dam and Downsville Dam on the east branch is progressing well. The completion of Neversink Dam is anticipated in 1952 and that of Downsville Dam in 1955.

Work is actively under way on the Neversink-Rondout Tunnel and on the (10-ft diameter) intake and outlet works through which water from Neversink Reservoir will be discharged into Rondout Reservoir. Similarly, work is progressing on the 11-ft, 4-in. East Delaware-Rondout Tunnel and intake that will convey water from Pepacton Reservoir to Rondout Reservoir and thence through the Delaware Aqueduct to Kensico Reservoir for distribution to the city (80).

The previously mentioned emergency Hudson River Pumping Station and river intake were completed in 1950 (80) (82).

Chester, Pa.—The Chester Municipal Authority has developed a new upland supply of 30-mgd safe yield from the 139.6 sq miles above the Octoraro Creek Dam (83).

A treatment plant having a capacity of 18 mgd is located just below the dam. Treated water is delivered by a pumping station having a capacity of 36 mgd, through 42-in. prestressed concrete pipe to two 2,500,000-gal prestressed concrete reservoirs placed 4 miles below the plant and 32 miles from Chester. Water flows to the city by gravity through 48-in. and 42-in. pipe lines. The project cost about $14,000,000. This project replaces the Delaware River supply for Chester, which was abandoned because of salt-water intrusion and pollution.

Cleveland, Ohio.—The City of Cleveland recently has placed in operation the Nottingham Filtration Plant—one of the major projects in an expansion program to increase and improve the supply of water to the Cleveland metropolitan area. The filtration plant has a nominal capacity of 100 mgd with provision for expansion to 150 mgd.

Raw water is taken from Lake Erie at a point 3.5 miles from shore and passes through 5 miles of intake of 10-ft. interior diameter to reach the plant, the land section of 1.5 miles being in tunnel. The water is lifted from a well at the end of the intake by deep-well-type pumps, each having a capacity of 27 mgd, and discharged into the building where the chemicals are added.

The treatment devices consist of 4 rapid-mix tanks; 12 flocculation tanks having detention periods of 45 min; 4 two-story settling tanks having 3.5-hour detention periods; 24 rapid sand filters having bottoms of the Wheeler type and surface wash of the Palmer type; and a clear-water underground reservoir of 25,000,000-gal capacity. The filtered water is pumped directly from the plant into the city's distribution systems.

The Nottingham Project, including the intake, filtration plant, and feeder mains to the distribution systems represents an expenditure of $21,000,000.

Miami, Fla.—A new calcination plant at Miami was put into operation in the spring of 1949 and resulted in a reduction in chemical costs from $16.17 per million gallons to $10.46 per million gallons.

A new treatment plant that is to have a final capacity of 80 mgd and is to be located approximately 13 miles southwest of the center of the city has been begun. The first 4 of 8 Dorr Hydro-Treator softening units, each having a capacity of 10 mgd are now nearing completion. Activated silica produced by partial neutralization of sodium silicate by CO_2 gas obtained from diesel engine exhaust will be used with lime to produce a clarified soft water. The plant will be supplied by 8 slotted cased wells approximately 90 ft deep and having diameters of 18 in. Each of the wells will produce from 6 mgd to 7 mgd (84) (85).

Cincinnati, Ohio.—Since 1946, Cincinnati has doubled the amount of water that can be delivered to the city, and has duplicated certain vital pumping and transmission features of its system. The Tennyson Pumping Station, with an initial capacity of 150 mgd and an ultimate capacity of 200 mgd, connects through a concrete-lined tunnel 13,620 ft long and having an 8-ft diameter—designed to carry 200 mgd—with the water treatment plant in the southeastern part of the city.

All piping in the station, including the venturi tubes, is of fabricated steel. This station is equipped with 6 bottom suction and discharge pumps, each having a capacity of 25 mgd. The contract cost of the pumping station is given as $1,931,770 (86) (87).

Chicago, Ill.—Estimated to cost in excess of $75,000,000, the Central District Filtration Plant will be designed to treat 950 mgd for the northern two thirds of the City of Chicago and more than 20 suburban communities (88) (89).

The site for the plant is on land immediately north of the United States Navy Pier. The plant will provide the same type of treatment as is now used at the South District Plant, and will be designed to allow filter operations at rates as high as 3.5 gal per min per sq ft.

There will be 8 two-story settling basins, each 330 ft wide and 425 ft long. Besides a tunnel connection to the existing William E. Dever and Carteret Harrison cribs, there will be additional direct intake facilities through 40 intake ports, each 6 ft by 8 ft.

Dallas, Tex.—The new Elm Fork Filtration Plant (having a capacity of 96 mgd) (90) is designed for ultimate expansion to have a capacity of 288 mgd. The old filtration plant has a capacity of 100 mgd, and the combined capacities of the two plants are deemed adequate for all possible needs until the year 2000. The filters are designed for capacities of 2 gal per sq ft per min, but other hydraulic components of the plant are designed for capacities of 4 gal per sq ft of filter surface per min. Four prestressed concrete clear wells of a total capacity of 14,000,000 gal and a 500,000-gal elevated wash water tank provide storage at the plant. A total of 5.5 miles of 66-in. pipe and 3.7 miles of 54-in. pipe convey the water to the city. (This pipe is a composite of steel cylinder and reinforced concrete.) The total contract costs were $8,062,100.

Denver, Colo.—During 1949 and 1950, the Denver Water Department continued work on its $30,000,000 program for the development and improvement of water facilities. During this period, an expenditure of $6,600,000 was made. The principal features involved were the laying of some 79 miles of

distribution mains in the City of Denver and also 10 miles of 90-in. reinforced concrete pipe in its transmission system between the production reservoirs and the distribution system (91) (80).

Salt Lake City, Utah.—During 1949 and 1950, work on the construction of the Provo River Project was continued by the USBR. This project involves the diversion of water from the Duchesne River through the Wasatch Mountains into the Provo River, where water will be stored in the Deer Creek Reservoir. This is a combined irrigation and municipal water project. It will be available for irrigation of the land between the Provo River and Salt Lake City. In addition, an aqueduct 41 miles in length will convey water from the Deer Creek Reservoir to Salt Lake City. The aqueduct was completed in 1950.

The 6-mile Duchesne Tunnel—estimated to cost in excess of $5,000,000—is a major construction feature of this project. The tunnel is 11 ft in diameter and will have a capacity of 650 cu ft per sec. At the close of 1950, work on the tunnel was approximately 60% completed.

The tunnel is scheduled for completion in 1953, and the 41,000,000-gal terminal reservoir on the aqueduct is to be completed in December, 1951 (91) (80).

San Diego, Calif.—During 1950, San Diego placed in operation the Alvarado Filtration and Softening Plant. It has a capacity of some 66 mgd, and was constructed at a cost of approximately $3,500,000. The water handled at the plant comes from the San Vincente Reservoir, which in turn is supplied largely with Colorado River water, through the aqueduct of the Metropolitan Water District of Southern California and the San Diego Aqueduct. The water is softened from an average hardness of 320 ppm to 125 ppm (92) (36).

Los Angeles, Calif.—The construction of the Baldwin Hills Reservoir will provide nearly 900 acre-ft of distribution storage for the rapidly growing areas in the southern part of Los Angeles. The earth fill dam creating the reservoir has a maximum height of 135 ft and contains 1,006,000 cu yd of compacted fill. The total cost of the Baldwin Hills Project is approximately $10,000,000 (93) (94).

Metropolitan Water District of Southern California.—In August, 1949, the enlargement of the F. E. Weymouth Softening and Filtration Plant near La Verne, Calif., was completed and the additional equipment was placed in service. The plant as originally constructed had a capacity of 100 mgd. The new capacity is 200 mgd. This work was completed at a cost of $3,850,000. The principal features of the expansion project include: 2 triple-compartment flocculating basins having rotating paddle mixers; 2 double-deck settling basins, each 200 ft square; a straight-line, drag-type sludge removal assembly; 12 rapid sand filter units; 12 base-exchange softener units; lime slakers and feeders; and 5 salt storage basins with a railway spur track. When completed to its ultimate size, this plant will have a capacity of 400 mgd (62).

Santa Barbara, Calif.—The Cachuma Project, Santa Barbara County, is designed to furnish additional water to the City of Santa Barbara and to the agricultural lands near that city. It involves the construction of the Cachuma Dam on the Santa Ynez River, thus creating a reservoir having a capacity of

210,000 acre-ft. The dam is an earth fill structure with a maximum height of some 275 ft. The 6-mile Tecolote tunnel will carry the water from the Cachuma Reservoir to the coast side of the mountains, from which it will be distributed by a conduit or aqueduct to Santa Barbara and to the irrigated sections. The estimated cost of this project is a little more than $32,000,000.

San Francisco, Calif.—During 1950, plans were prepared for the construction of the Cherry Valley Dam of the Hetch Hetchy Aqueduct system of the City of San Francisco. This structure is to be located on the Cherry River, a tributary of the Tuolumne River, and it is to be a joint venture by the City of San Francisco, the Corps of Engineers, United State Department of the Army, and the Modesto and Turlock irrigation districts. San Francisco's portion of the expense will be approximately $4,000,000 of a total estimated cost of $13,000,000. The proposed dam will create a reservoir having a capacity of approximately 86,000,000,000 gal, or approximately three fourths of the capacity of the Hetch Hetchy Reservoir. Work is expected to begin in 1951.

In June, 1950, work was completed on the installation of 33 miles of 61-in. steel and concrete pipe across the San Joaquin Valley. The balance of the line is planned for completion in the latter part of 1951. This will give a paralleling line 47 miles long across the San Joaquin Valley. The combined capacity of the lines will be approximately 140 mgd, and the cost of this work will be approximately $12,000,000.

In 1950, contracts were awarded for the installation of some 33.75 miles of pipe with diameters of from 72 in. to 78 in. from the West Portal of the Coast Range Tunnel near Irvington (Calif.) to the East Portal of the Pulgus Tunnel near Redwood City (Calif.). The Hetch Hetchy Aqueduct now has two lines connecting these two tunnels, both lines crossing the south end of San Francisco Bay near the Dumbarton Bridge. The new line will skirt around the sound end of San Francisco Bay, thereby eliminating underwater crossings. It will also make water available in the San Jose area. Steel cylinder, reinforced concrete pipe with rubber gasket joints comprises 16.7 miles of this line. The remainder of 17.1 miles is to be steel pipe, cement-mortar lined and coated. The total cost of the project is $8,344,000 (95) (96).

East Bay Municipal Utility District, Oakland, Calif.—In 1949, construction was completed on the installation of some 81 miles of pipe 67 in. in diameter on the Mokelumne Aqueduct across the San Joaquin Valley. The new line parallels a steel line 65 in. in diameter installed during the period from 1926 to 1928. The new line contains 66 miles of 67-in. steel pipe, cement-mortar lined and coated, and 15 miles of 67-in. reinforced concrete (steel cylinder) pipe with lead gasket joints. The total cost of this project was slightly over $21,500,000 (52) (97) 98).

Seneca Reservoir, providing distribution system storage of 30,000,000 gal was placed in service in 1950. This is an open reservoir, entirely in excavation and constructed on top of a ridge. Because of pervious reservoir foundation material and a location above a residential section, it was necessary to use exceptional precautions against seepage losses.

Eugene, Ore.—The Hayden Bridge Filtration Plant was put into service last summer, using two of the six units in the master plan which specifies an ultimate

capacity of 75 mgd. The new plant (with a capacity of 25 mgd) receives screened water from the McKenzie River. After filtration, its two-speed pumps force the water to Eugene through a steel supply line 6 miles long and having a 45-in. diameter. The total cost of the filtration plant was approximately $800,000. The transmission line, raw water line, and wash water drain line were all installed by crews of the Water and Electric Board at a cost of $872,000 (99) 100).

San Juan, Puerto Rico.—Since the last report of this Committee, work has gone forward on the Loiza Dam and Filtration Plant (101) (102). The filtration plant, built to one half its ultimate capacity of 60 mgd, is in operation using a temporary pumped supply. Concrete work on the dam, a structure 50 ft high by 700 ft long, is moving forward rapidly.

Other Notable Projects.—Eight of the projects that could be mentioned in this connection are as follows:

Location	Type of work
Portland, Me.	Intake and supply main (80) (103)
Baltimore, Md.	Tunnel and dam (39)
Richmond, Va.	Filter plant additions (104)
Saginaw-Midland, Mich.	Intake, pumping stations, and pipe line (105)
Detroit, Mich.	Tunnel (80)
Des Moines, Iowa	Filter plant (106)
Houston, Tex.	Wells (107)
Long Beach, Calif.	Distribution storage (108)

Recent Investigations and Reports

Several investigations and reports relating to water supply policies and projects have been made within the period covered by this report. A few of the more important ones are described subsequently.

Report of The President's Water Resources Policy Commission.—The report of The President's Water Resources Policy Commission (109) was released on December 1, 1950. The report was compiled under the direction of a seven-man commission charged with the task of appraising

> "the uses to which land and water resources have been put and, with consideration for the present and future needs of the nation, to make recommendations for a national policy to guide the government's actions."

This commission recommended, among other things, that planning for water use be on a river-basin basis and that uniform policies be adopted by all federal agencies. Furthermore, it made recommendations as to methods of coordinating construction work and as to repayment of project costs. Certain rather serious differences in policies of financing and repayment exist between the EJC report and the commission's report. These differences were brought out and discussed with some thoroughness at the annual conference of the AWWA in May, 1951, by Samuel B. Morris (110), Abel Wolman (111), and Malcolm Pirnie (112), Members, ASCE.

EJC Report on National Water Policy.—In connection with The President's Water Resources Policy Commission, a panel of the EJC was organized in

1950 to prepare (113) "a statement of desirable policy with respect to the conservation, development, and use of the national water resources."

Detailed reports on nine different phases of water supply utilization and control were prepared by task committees as follows: (*a*) Domestic and industrial water supply and pollution; (*b*) flood control, including water flow retardation; (*c*) navigation and inland water transportation; (*d*) irrigation; (*e*) hydroelectric power; (*f*) recreation, fish, and wildlife; (*g*) basic water resources information; (*h*) land drainage; and (*i*) policies of general applicability.

The report of the panel was completed in June, 1950, and was submitted to the Water Resources Policy Commission (113). In general, the various task committees reviewed the basic factors in water supply development in the United States and made specific recommendations as to the part the federal government should take in carrying out water policies. The EJC panel favored local control and financing of water projects except where it could be proved that the national interest was at stake. The committee on policies of general applicability recommended a system of financing and evaluating water projects so that the cost would be properly allocated and so that projects that would not be self-supporting would not be built.

Report on Utilization of the Waters of the Delaware River Basin.—In 1949, New York, New Jersey, and Pennsylvania authorized the Interstate Commission on the Delaware River Basin to report on whether or not it was feasible and advisable to construct an integrated water project in the Delaware River Basin above Trenton, N. J. for the mutual benefit of the states in the basin. The commission engaged two consulting engineering firms to make jointly the detailed investigations and report. In September, 1950, the report (114) was submitted to and approved by the commission.

The report recommended a two-stage project that will provide for the storage of flood flows for filling future water supply needs of metropolitan areas in the states of the basin and for increasing river flow during dry periods. The two stages are as follows:

Stage 1.—This includes a storage reservoir having a capacity of 118,000,000,000 gal, on the west branch of the Delaware River near Cannonsville, N. Y.; a diversion dam on the main river near Barryville, N. Y.; a 15-mile tunnel, 25 ft in diameter, from Barryville to a large storage reservoir of 278,000,000,000-gal capacity, formed by a dam on the Neversink River near Godeffroy, N. Y., and a cutoff dam in Basher Kill Valley above Wurtsboro, N. Y.; and a 65-mile pressure tunnel averaging about 15 ft in diameter between Godeffroy Reservoir and the southern terminus of New York City's two existing main supply tunnels in Brooklyn. This stage is designed to provide a gravity water supply of 465 mgd to northeast New Jersey and New York and to increase river flow in dry weather from about 1,800 cu ft per sec to about 4,000 cu ft per sec. This supply is expected to fill the water needs of New York City and northeastern New Jersey for the next thirty-year period and to provide a new source of supply for Philadelphia when and as needed. An alternate to Stage 1 of the project includes the construction of a dam on the main river at Wallpack Bend that would permit increasing minimum river flows to the equivalent to 4,800

cu ft per sec at Trenton and is necessary in connection with providing a supply to the Philadelphia area.

Stage 2.—This includes two additional storage reservoirs and is designed to provide a total additional water supply of 1,000 mgd to northeastern New Jersey and to New York City, and 800 mgd to Philadelphia and adjacent areas in Pennsylvania and New Jersey, and also to provide the river regulation described under Stage 1. These water supply quantities are the estimated future needs for fifty or more years.

The reasons for increasing dry weather river flows are to retard salt-water intrusion below Philadelphia and to improve generally recreational and sanitary conditions on the entire river.

In all four of the Delaware River Basin states, legislation recently has been considered to establish a commission or authority to construct the project. New Jersey and Delaware have passed this legislation and it is under consideration by New York and Pennsylvania.

Investigation of Water Supply for Synthetic Liquid Fuels Plants.—Because of the many portions of the country investigated and the large quantities of water involved, the studies of water resources in twenty-six states and Alaska—in connection with a survey of potential sites for the construction of synthetic liquid fuels plants—are of interest. The purpose of the survey, conducted under contract for the United States Army and the United States Bureau of Mines, was to determine general areas suitable for the construction of synthetic liquid fuels plants. No attempt was made to determine the best area or areas. The synthetic liquid fuels plants included those for the conversion of coal and natural gas to gasoline or other liquid fuels and for the removal of oil and gasoline from oil shales. A large-scale synthetic liquid fuels industry would require very large volumes of water, most of which would be for cooling purposes.

In general, it was found that adequate supplies of water would be available, although in most cases it would be necessary to recirculate the cooling water through cooling towers in order to get sufficient cooling capacity. The results of the survey have not yet been published, but presumably will be available at a later date through the Bureau of Mines.

However, it may be stated that, except for a few very dry areas in the Rocky Mountain states and upper Missouri River Valley, there is every indication that sufficient water is available for many more synthetic liquid fuels plants than are likely to be built in the next several years. In almost all the areas studied, ground water was not available in sufficient quantities to supply the plants.

Industrial Supply Near Charleston, S. C.—An important industrial water supply development appears in the making at Charleston (115), where it is proposed to divert the Santee-Cooper River into a storage reservoir formed by damming the Back River only a few miles from the city. A tunnel would carry water to industrial establishments along the navigable lower Cooper River. The project is expected to develop 10,000,000,000 gal per day of fresh water at a construction cost of about $6,000,000. Detailed studies are under way on this project.

Valuation and Rates

There have been no outstanding court decisions in reference to water works rate making since the last report of this Committee.

A joint report of ASCE committees and the American Bar Association and of representatives of the AWWA, National Association of Railroad and Utility Commissioners, Municipal Finance Officers Association, Federation of Sewage Works Associations, American Public Works Association, and Investment Bankers Association, concerning the rate structures for water and sewage works (116) was published in 1950. This report is a comprehensive study of how a publicly-owned or privately-owned utility should establish fair rates for water and sewage works. In it, the following fundamental principle is stated:

> "The needed total annual revenue of a water or sewage works shall be contributed by users and non-users (or by users and properties) for whose use, need and benefit the facilities of the works are provided approximately in the proportion to the cost of providing the use and the benefit of the works."

During the period covered by this report, costs of construction and operation have continued to increase and the net income of many water works systems has declined, even though there has been a general increase in water consumption and gross revenues. Many systems, both publicly-owned and privately-owned, have found it necessary to increase rates. Among these are Detroit; Long Beach and Pasadena, (Calif.); Hartford, Conn.; Minneapolis, Minn., and St. Paul, Minn.; and the Indianapolis Water Company in Indiana.

A series of fourteen articles in the *American City*, beginning with the April, 1948, issue and ending with the June, 1949, issue, entitled "Modern Water Rates and Service Charges" lists current rates of many water works systems in the United States.

Miscellaneous Developments

Among recent miscellaneous developments of interest are cloud "seeding" to stimulate rainfall, the reclamation of waste waters for re-use, and the desalting of sea water.

Rainmaking.—The discovery that the seeding of moisture-laden clouds with dry ice and silver iodide crystals could at times stimulate rainfall invoked much publicity and much interest, both lay and technical. The New York City Department of Water Supply, Gas, and Electricity used the method to increase rainfall on its watershed, but conclusive evidence on results is lacking.

Cloud seeding has been carried on extensively in the southwest and has raised legal questions regarding water rights and responsibility for damages (117). In one rainmaking operation involving twenty-seven flights, the "rainmaker" estimated that from 6,000 acre-ft to 12,000 acre-ft of water were precipitated.

Further development is required, but it seems probable that cloud seeding activities can produce some additional rainfall and redistribute some of the rainfall that would have occurred naturally.

Reclamation of Waste Waters for Re-Use.—For some years the effluent from the Back River Sewage Treatment Plant at Baltimore has been used as indus-

trial process water by the Bethlehem Steel Company (118). In the area around Los Angeles, where recharge of underground formations is very important, it was proposed to reopen as a water reclamation plant (119) the Tri-Cities Treatment Plant, which was abandoned in 1948. This plant would return for percolation into the Rio Hondo Channel 9,000 acre-ft of reclaimed water annually. Further treatment for recharge purposes is believed possible up to 50,000 acre-ft or more annually. It was found that percolated waters were bacteriologically safe below a depth of 7 ft from the ground surface.

Consideration was given to the use of reclaimed sewage from San Francisco for irrigation water in the Santa Clara Valley. However, when it was found that reclaimed sewage from the Richmond-Sunset Plant would cost more than twice as much as better water from the Sacramento-San Joaquin Delta, further consideration was dropped (120).

Desalting Sea Water.—Progress in cheaply desalting large volumes of sea water for domestic consumption was minor during the period of this report. W. W. Aultman, M.ASCE (121), compared the three general methods—mechanical, chemical, and electrical—and concluded that under present conditions the cheapest method was vapor-compression distillation, at a cost of over twelve times that of large-quantity municipal water production. He further concludes:

> "Within the foreseeable future, and in the light of current technical knowledge, there appears to be no possibility that it will be economically feasible to turn to the ocean as a source of domestic, industrial or agriculture water along either coast of the United States."

Nevertheless, distillation methods are continuing to be used to produce limited quantities of water for human consumption where rainfall is too limited to produce natural supplies (121). Measures have been introduced in the United States Congress during the past year to appropriate money for use in stimulating research in this field.

Respectfully submitted,

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APPENDIX. BIBLIOGRAPHY ON WATER SUPPLY

(1) **"The California Water Plan,"** by William L. Berry, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 381.
(2) **"Ground Water in California,"** by J. F. Poland, *Mining Engineering*, Vol. 187, 1950, p. 279.
(3) **Discussion of "Ground Water in California,"** by J. F. Poland, *ibid.*, p. 1168.

(4) **"New Jersey Ground Water Supplies,"** by T. C. Nelson, *Journal*, Am. Water Works Assn., Vol. 41, 1949, p. 507.

(5) **"Depletion of Ground Water in New Jersey,"** by H. C. Barksdale, *ibid.*, p. 511.

(6) **"Report of Committee for Survey of Ground Water Supplies in New England,"** *Journal*, New England Water Works Assn., June, 1949, p. 175.

(7) **"Using Runoff for Ground Water Recharge,"** by E. T. Erickson, *Journal*, Am. Water Works Assn., Vol. 41, 1949, p. 647.

(8) **"Conservation of Ground Water Resources,"** by W. F. Welsch, *Water Works Engineering*, Vol. 102, 1949, p. 708. (*a*) p. 741.

(9) **"Seismic Reconnaissance for Ground-Water Development,"** by D. Linehan and S. Keith, *Journal*, New England Water Works Assn., March, 1949, p. 76.

(10) **"Geologic and Hydrologic Factors in the Perennial Yield of the Biscayne Aquifer,"** by G. G. Parker, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 817.

(11) **"The Water Situation in the United States,"** by C. L. McGuinness, *Geological Survey Circular 114*, Superintendent of Documents, Govt. Printing Office, Washington, D. C. 1951.

(12) **"Municipal Water Use in the United States,"** by W. B. Langbein, *Journal*, Am. Water Works Assn., Vol. 41, 1949, p. 997.

(13) **"Mortality in Water Wells,"** by H. E. Hudson, Jr., and J. L. Geils, paper presented at the 71st Annual Conference of the Am. Water Works Assn., 1951.

(14) **"Annual Summary,"** September, 1949–September, 1950, U.S.G.S., Washington, D. C., March, 1951.

(15) **"Winnipeg's Flood Emergency Organization,"** by W. D. Hurst, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 1095.

(16) **"Kansas River Floods of July Exceed All Previous Records,"** *Water Works Engineering*, Vol. 104, 1951, p. 858.

(17) **"Water Supply Notes on the Kansas Flood,"** *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 681.

(18) **"Effect of Land Use on Reservoir Siltation,"** by H. E. Hudson, Jr., C. B. Brown, H. B. Shaw, and J. S. Longwell, *ibid.*, Vol. 41, 1949, p. 913.

(19) **"Pollution Abatement Policy,"** by T. R. Camp, *Transactions*, ASCE, Vol. 116, 1951, p. 252.

(20) **"Industrial Stream Pollution Abatement,"** by L. L. Hedgepeth, *ibid.*, p. 919.

(21) **"Water Pollution in the United States,"** *Public Health Service Publication No. 64*, Superintendent of Documents, U. S. Govt. Printing Office, Washington, D. C.

(22) **"Recently Enacted Federal Water Pollution Control Legislation,"** by M. Le Bosquet, Jr., *Sewage and Industrial Wastes*, Vol. 22, 1950, p. 239.

(23) **"Annual Report, 1949,"** National Council for Stream Improvement, Inc., New York, N. Y.

(24) **"Annual Report, 1950,"** National Council for Stream Improvement, Inc., NewYork, N. Y.

(25) **"High Court Affirms Ohio River Compact,"** *Engineering News-Record*, April 19, 1951, p. 24.

(26) **"Industry and Pollution Abatement Policies, Problems and Progress in the Ohio River Valley,"** by E. J. Cleary, *Water and Sewage Works*, Vol. 97, 1950, p. 119.

(27) **"Water Quality in the Middle Atlantic States,"** by S. K. Love, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 257.

(28) **"Pennsylvania Clean Stream Program,"** by H. E. Moses, *ibid.*, p. 146.

(29) **"California Pollution Control Legislation,"** by L. W. Grayson, *ibid.*, p. 1133.

(30) **"Classification and Standards of Water Quality and Purity,"** N. Y. Water Pollution Control Board, *ibid.*, p. 1137.

(31) **"Sanitary Engineering and Waste Disposal Problems in the Atomic Energy Industry,"** by A. E. Gorman, Proceedings of the 6th Industrial Wastes Conference, *Engineering Bulletin 35*, No. 6 (Extension Series No. 76), Purdue Univ., Lafayette, Ind., Oct. 1951.

(32) **"Studies on Radioisotope Removal by Water Treatment Processes,"** by Rolf Eliassen, W. J. Kaufman, J. B. Nesbitt, and M. I. Goldman, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 615.

(33) **"A Method for Decontaminating Small Volumes of Radioactive Water,"** by R. A. Lauderdale and A. H. Emmons, *ibid.*, p. 327.

(34) **"Congress Must Decide If Supreme Court Is to Settle Colorado River Dispute,"** *Engineering News-Record*, March 24, 1949, p. 19.

(35) **"Congress Offers Colorado Compromise,"** *ibid.*, June 30, 1945, p. 13.

(36) **"Major Projects—Water Use and Control,"** *ibid.*, March 29, 1951, p. 192.

(37) **"Basic Water Use Doctrine and State Water Control Agencies,"** Committee Report, R. Hazen, Chairman, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 755.

(38) **"Water Law with Special Reference to Ground Water,"** *Geological Survey Circular No. 117*, U.S.G.S., Washington, D. C., June, 1951.

(39) **"Overflow Dam Diverts Water to City,"** *Engineering News-Record*, March 1, 1951, p. 38.

(40) **"Treatment of Foundations for Large Dams by Grouting Methods,"** by A. W. Simonds, Fred H. Leppold, and R. E. Keim, *Transactions*, ASCE, Vol. 116, 1951, p. 548.

(41) **"Uplift Pressures in Concrete Dams,"** by Kenneth B. Keener, *ibid.*, p. 1218.

(42) **"Building a Trio of Earthfill Dams,"** *Engineering News-Record*, January 6, 1949, p. 60.

(43) **"Manual of British Water Supply Practice,"** The Inst. of Water Engrs., London, England, 1950, p. 198.

(44) **"Engineering for Dams,"** by Joel D. Justin, Julian Hinds, and William P. Creager, John Wiley & Sons., Inc., New York, N. Y., 1944, Vol. III, p. 701.

(45) **"Compaction of Cohesive Soils,"** Progress Report of the Subcommittee on Consolidation of Materials in Earth Dams and Their Foundations, *Proceedings-Separate No. 48*, ASCE, December, 1950.

(46) **"The Geochemistry of Earthwork,"** by Hyde Forbes, *Transactions*, ASCE, Vol. 116, 1951, pp. 637–670.

(47) **"Design of Steel Ring Flanges for Water Works Service,"** by R. E. Barnard, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 931.

(48) **"Design Standards for Large Diameter Steel Water Pipe,"** by W. H. Catis, *ibid.*, p. 860.

(49) **"Design of Prestressed Concrete Cylinder Pipe,"** by H. F. Kennison, *ibid.*, p. 1049.

(50) **"Tests of Prestressed Concrete Cylinder Pipe,"** by F. E. Seaman, *ibid.*, p. 1065.

(51) **"Tentative Standard Specifications for Reinforced Concrete Water Pipe—Steel Cylinder Type, Prestressed,"** *ibid.*, Vol. 41, 1949, p. 1113.

(52) **"Origin and Achievements of the Board of Water Supply, City of New York,"** Board of Water Supply, New York, N. Y., 1950.

(53) **"The Hudson River Emergency Pumping Plant of the City of New York,"** by G. R. Rich, *Journal*, Boston Soc. of Civ. Engrs., April, 1951, p. 165.

(54) **"Automatic Pump Control,"** by Milford E. Rogers, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 383.

(55) **"Proper Pump Selection Reduces Cost and Increases Efficiency,"** by E. Condict, *Water Works Engineering*, Vol. 104, 1951, p. 754.

(56) **"The Municipal Water Supply of the City of Waterbury,"** by W. H. Hoovel, 59th Annual Report, Connecticut Soc. of Civ. Engrs., 1943, p. 182.

(57) **"Use of Alternating Current Network Calculator in Distribution System Design,"** by M. V. Suryaprakasam, G. W. Reid, and J. C. Geyer, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 1154.

(58) **"Direct Reading Electric Analyzer for Pipeline Networks,"** by M. S. McIlroy, *ibid.*, p. 347.

(59) **"Above Ground Pipeline Sections of Mokelumne Aqueduct,"** by J. W. Trahern, *ibid.*, p. 189.

(60) **"Capacity and Loadings of Suspended Solids Contact Units,"** Committee Report of Am. Water Works Assn., *ibid.*, Vol. 43, 1951, p. 263.

(61) **"Economics of Water Softening,"** by Louis R. Howson, *ibid.*, p. 253.

(62) **"World's Largest Water Softening Plant,"** by W. W. Aultman, *Water and Sewage Works*, Vol. 96, 1949, p. 456.

(63) **"Elements of Filter Design,"** by Richard Hazen, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 208.

(64) **"Further Research in Diatomite Filtration,"** by J. M. Sanchis and J. C. Merrell, Jr., *ibid.*, p. 475.

(65) **"Corrosion Control at New Haven, Conn.,"** by Marshall Wellington, *Water and Sewage Works*, Vol. 98, 1951, p. 304.

(66) **"Factors Influencing the Efficiency of Activated Carbon,"** by D. Colebaugh, J. Filicky, and A. Hyndshaw, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 322.

(67) **"Controlling Taste, Odor and Color with Free Residual Chlorination,"** by T. M. Reddick, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 545.

(68) **"Effect of Stepwise Chlorination and Taste and Odor Producing Intensity of Some Phenolic Compounds,"** by M. B. Ettinger and C. C. Ruchhoft, *ibid.*, p. 561.

(69) **"Developments in the Chlorine Dioxide Process,"** by R. Aston, *ibid.*, p. 151.

(70) **"Philadelphia Improvement Program,"** by M. G. Mansfield, *ibid.*, p. 645.

(71) **"Resistance of Organisms to Chlorine,"** by P. W. Kabler, *ibid.*, p. 553.

(72) **"Fluoridation in the Prevention of Dental Caries,"** Am. Dental Assn., February, 1951.

(73) **"How Far Has Fluoridation Developed in the U. S.?"** *Water Works Engineering*, Vol. 104, 1951, p. 336.

(74) **"Advances in Chemical and Colorimetric Methods,"** by J. J. Connors, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 33.

(75) **"The Versenate Titration for Total Hardness,"** by H. Diehl, C. A. Goltz, and C. C. Hach, *ibid.*, p. 40.

(76) **"Total Hardness Determination of Direct Colorimetric Titration,"** by J. D. Betz, and C. A. Noll, *ibid.*, p. 49.

(77) **"Analytical Instruments Used in the Modern Water Plant Laboratory,"** by S. K. Love, *ibid.*, Vol. 43, 1951, p. 725.

(78) **Discussion** by J. R. Baylis **of "Analytical Instruments Used in the Modern Water Plant Laboratory,"** by S. K. Love, *ibid.*, p. 735.

(79) **"Colorimetric Determination of Metals in Sewage and Industrial Wastes,"** by P. G. Butts, A. R. Gahler, and M. G. Mellon, *Sewage Works Journal*, Vol. 22, 1950, p. 1543.

(80) **"Major Projects—Water Supply and Sanitation,"** *Engineering News-Record*, March 29, 1951, p. 264.

(81) **"Chicopee Valley Aqueduct,"** by S. M. Dore, *Journal*, New England Water Works Assn., Vol. 64, No. 1, 1951, p. 13.

(82) **"New York Has Temporary Pumping Plant Ready for Emergency Use,"** by T. Eide, *Water Works Engineering*, Vol. 104, 1951, p. 345.

(83) **"Chester, Pa., Develops New Water Supply Source,"** by F. S. Friel, *ibid.*, p. 36.

(84) **"Problems of Water Supply and Treatment at Miami, Fla.,"** by W. A. Glass, C. F. Wertz, A. P. Black, and C. R. Henry, *ibid.*, p. 324.

(85) **"Miami's Hialeah Treatment Plant,"** by C. R. Henry, *Water and Sewage Works*, Vol. 98, 1951, p. 143.

(86) **"Getting Ready to Drive Deep Water Tunnel,"** *Engineering News-Record*, August 4, 1949, p. 32.

(87) **"Twice as Much Water for Cincinnati,"** by R. E. Duhme, *ibid.*, September 22, 1949, p. 30.

(88) **"New Chicago Filters Will Be Triple Size of South Plant,"** *Water Works Engineering*, Vol. 103, 1950, p. 450.

(89) **"New Filter Plant to Be World's Largest,"** by F. C. Gordon, *American City*, Vol. 65, No. 7, 1950, p. 69.

(90) **"Dallas Is Winning Its Battle for Water,"** *Engineering News-Record*, May 3, 1951, p. 35.

(91) **"Denver Completes 90-Inch Concrete Conduit,"** by D. D. Gross, *Civil Engineering*, Vol. 20, 1950, p. 439.

(92) **"Some Major Waterworks Projects,"** *Engineering News-Record*, March 23, 1950, p. 125.

(93) **"Annual Report of the Los Angeles Department of Water and Power,"** 1949.

(94) **"Annual Report of the Los Angeles Department of Water and Power,"** 1950.

(95) **"Annual Report of the Public Utilities Commission,"** San Francisco, Calif., 1949.

(96) **"Annual Report of the Public Utilities Commission,"** San Francisco, Calif., 1950.

(97) **"Annual Report of the East Bay Municipal Utility District,"** Oakland, Calif., 1949.

(98) **"Annual Report of the East Bay Municipal Utility District,"** Oakland, Calif., 1950.

(99) **"New Water Supply Plant, Eugene, Oregon,"** by W. J. Moore and W. A. Moore, *Water Works Engineering*, Vol. 104, 1951, p. 662.

(100) **"Newest West Coast Water Plant Will Serve Eugene, Ore.,"** *Engineering News-Record*, November 24, 1949, p. 41.

(101) **"Building Water Works in Puerto Rico,"** by A. J. Fox, Jr., *ibid.*, April 26, 1951, p. 32.

(102) **"Puerto Rico's $40,000,000 Water Supply and Sanitation System,"** *Water Works Engineering*, Vol. 102, 1949, p. 297.

(103) **"Full Circle, Continuous Concreting Preserves Tunnel's Rock Bore,"** *Engineering News-Record*, January 4, 1951, p. 32.

(104) **"New Water Purification Plant at Richmond, Va.,"** by M. C. Smith, *Water Works Engineering*, Vol. 103, 1950, p. 620.

(105) **"Saginaw-Midland Supply Project Begins Operation,"** Louis R. Howson, *ibid.*, Vol. 102, 1949, p. 415.

(106) **"Des Moines Expands Supply and Installs Softening Plant,"** by V. R. Kneer, *ibid.*, Vol. 103, 1950, p. 482.

(107) **"How Houston Built Ten New Wells,"** by A. E. Fawcett, Jr., *American City*, Vol. 65, No. 1, 1950, p. 84.

(108) **"40,000,000 Gallons Stored in 12 Steel Tanks at Long Beach,"** by C. E. Wells, *Western Construction*, Vol. 25, No. 10, 1950, p. 82.

(109) **"Report of The President's Water Resources Policy Commission,"** Vol. I—A Water Policy for the American People; Vol. II—Ten Rivers in America's Future; Vol. III—Water Resources Law. Superintendent of Documents, Govt. Printing Office, Washington, D. C., December, 1950.

(110) **"Review of the Report of The President's Water Resources Policy Commission,"** by Samuel B. Morris, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 391.

(111) **"Water Policy As the Engineers See It,"** by Abel Wolman, *Journal*, Am. Water Works Assn., Vol. 43, 1951, p. 401.

(112) **"Objectives of a National Water Policy,"** by Malcolm Pirnie, *ibid*,. p. 409.

(113) **"Principles of a Sound National Water Policy,"** Engineers Joint Council, July, 1951.

(114) **"Report on the Utilization of the Waters of the Delaware River Basin,"** by Malcolm Pirnie, Engrs., and Albright & Friel, Inc., Cons. Engrs. Interstate Comm. on the Delaware River Basin, Philadelphia, Pa., 1950.

(115) **"Ten Billion Gallons a Day,"** by H. R. Sass, *The Saturday Evening Post*, Vol. 223, No. 28, 1951, p. 24.

(116) **"Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works,"** *ASCE Bulletin No. 2, Ohio State Law Journal*, Vol. 12, 1951, p. 151.

(117) **"Planes 'Make' Heavy Rains; Lawyers Study Legal Aspects,"** by N. A. Bowers, *Engineering News-Record*, January 20, 1949, p. 57.

(118) **"Industrial Water Supply from Processed Sewage Treatment Plant Effiuent at Baltimore, Md.,"** by Abel Wolman, *Sewage Works Journal*, Vol. 20, 1948, p. 15.

(119) **"Los Angeles Considers Reclaiming Sewage Water to Recharge Underground Basins,"** by Harold E. Hedger, *Civil Engineering*, Vol. 20, 1950, p. 323.

(120) **"Cost of Reclaimed Water Found Excessive in California,"** *Engineering News-Record*, May 17, 1951, p. 26.

(121) **"Desalting Sea Water for Domestic Use,"** by W. W. Aultman, *Journal*, Am. Water Works Assn., Vol. 42, 1950, p. 786.

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